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Evaluating the Ecological Sustainability of Agrifood Land in Ethnic Minority Areas: A Comparative Study in Yunnan China

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Abstract: Agrifood land plays a crucial role in indigenous communities. However, there is limited study on the overall sustainability and inter-ethnic comparison of agrifood lands across ethnic groups. To address these gaps, we developed a visual eco-efficiency framework of ecological footprint, biocapacity, and ecological benefit to evaluate the sustainability of agrifood land in these regions, as well as analyzed the sustainability of agrifood land and examined its explanatory factors across six ethnic groups in the Yunnan Province of China. The results showed that the ecological benefits of agrifood lands fluctuated in a low ecological deficit, and the eco-efficiency of different ethnic groups varied significantly, from 2010 to 2020. Moreover, redundancy analysis showed that cash crops, forestry, fishery, and livestock were major contributors to the eco-efficiency of agrifood lands in ethnic groups, rather than the commonly accepted staple foods. Another finding revealed that the contribution of urbanization rate to the eco-efficiency of agricultural food land had a rule of reversed U and was influenced by the annual average temperature and the ethnic population rate. Our study not only provided a visual framework for evaluating the sustainability of agrifood land in ethnic areas but also shed new light on its explanatory factors across different ethnic groups. The study served as a scientific foundation for the investigation, monitoring, and management of indigenous agriculture by governments and the agricultural sectors.

Keywords: agrifood land; sustainability; ecological benefits; ethnic minority; redundancy analysis

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1. Introduction

Agrifood lands are critical to indigenous communities in ethnic areas [1,2]. They are land use methods that are created and passed down from generation to generation based on local resources, climate, and topography. Their patterns involve agriculture, forestry, herding, and fishing and are spread across different ecological regions such as plains, hills, and plateaus. Rice terrace agroecosystems of mountain ethnics, oasis agriculture systems of desert ethnics, and nomadic systems of steppe ethnics typically provide a variety of food resources (e.g., rice, sorghum, millet, maize, wheat, cassava, beans, cattle, swine, and poultry) for indigenous people [1,3–7]. These land uses have unique agri-pastoral varieties, associated knowledge, and technology systems that support not only the balance of local natural ecosystems but also the social structures and cultural systems of local ethnic groups [2,8–13].

With the widespread adoption of modern agricultural production technology, characterized by intensive chemical inputs, mechanization, and large-scale production, cereal yields have increased. However, it has also led to negative impacts such as reduced agricultural biodiversity, environmental pollution, rural population loss, land abandonment, as well as the conversion of agrifood land into urban and industrial land [14–16]. Furthermore, extreme climate change presents a significant threat to the sustainable development of agrifood lands in ethnic areas dominated by smallholders. As a result, issues such as reduced cereal yields, shortened planting seasons, water crises, and pest outbreaks have been identified, creating challenges to food security [17,18]. In response to changes in and protection of indigenous agricultural systems, the Food and Agriculture Organization of the United Nations (FAO) and governments are active in launching projects, such as Biocultural Refugia, the Globally Important Agricultural Heritage Systems (GIAHS) [19], the Nationally Important Agricultural Heritage Systems (NIAHS) in China [20,21], and the Agricultural Heritage Protection Program in Brazil and Italy [22]. Although these initiatives have demonstrated positive impacts on agrifood lands in ethnic areas through landscape conservation, food security, and the promotion of local cultural identity [23,24], their impacts are limited due to the small scale of the heritage sites.

In China, the agrifood lands, which continue to be produced locally, are mainly distributed in economically backward ethnic minority areas, especially the ecologically fragile mountainous, hilly, and upland areas, where topographic conditions have limited cultivated land resources, small and scattered plots, and make mechanization of agriculture difficult, resulting in local agriculture such as rice and fish terracing systems, montane dry-cropping complexes, sub-forest cropping systems, and livestock farming systems [17,25]. Due to the inaccessibility and low productivity, the agrifood system in these areas shows a tight balance of "resource-environment-society", i.e., the production and consumption of agrifood resources, which almost meet the needs of the indigenous people, do not exceed the carrying capacity of the resources and environment [25]. At the same time, agrifood land use patterns transmitted in ethnic areas are changing due to various internal and external factors such as urbanization, climate change, modern agricultural technologies, and changes in food structure [26,27]. Although many scholars have conducted effective studies from perspectives of economic valuation, biological valuation, and social-cultural valuation on the topics of food security [28–30], ecosystem services [31], biodiversity [1,11], and farmers' livelihoods in ethnic minority areas [32,33], etc. However, the overall assessment of the sustainability of agrifood land in ethnic areas and comparative studies among different ethnic groups is still limited.

The ecological footprint model is an effective way to quantitatively assess the impact of human activities on nature. It assesses the impact of human activities on the ecosystems of a given region by comparing the eco-efficiency of the region primarily through two indicators of ecological footprint and biocapacity [34,35]. If the ecological footprint is greater than the biocapacity, the socioeconomic development of the area is in an unsustainable condition; it is called the ecological deficit. Conversely, it is called the ecological surplus. Ecological footprint models have been widely used in empirical studies at different geographic locations and spatial scales, particularly in resource-intensive regional and industrial sustainability assessments [36–38].

A major contribution of this paper is that it provides valuable insights for policymakers and practitioners seeking to promote ecologically sustainable development in ethnic areas through effective agrifood land management. Moreover, the findings can be used as a basis for investigating agrifood land development capacities in other regions and countries to understand the current status of sustainable agrifood land development.

Thus, the paper aims to add new insights to the study of agrifood land in ethnic areas and explore the details of its influencing factors. The specific objectives are (1) to assess the change in ecological efficiency of agrifood land in the Yunnan ethnic areas from 2010 to 2020, (2) to compare the eco-efficiency differences of agrifood land of different ethnic groups, and (3) to explain their influencing factors.

2. Study Area and Methods

2.1. Study Area

The study area is located in the mountainous plateau of Yunnan Province, China. A total of 87.21% of the area is at an altitude of 1000 to 3500 m [39]. Plains, mesas, hills, and mountains account for 4.85%, 1.55%, 4.96%, and 88.64%, respectively. The stereo-climate characteristics are significant in this area, with small annual temperature differences (10–12 °C) and large diurnal temperature differences (12–20 °C) [39]. The temperature changes with the topography of the vertical anomaly, in every 100 m elevation rise, an average temperature decline of 0.6–0.7 °C [39]. In addition, rainfall distribution varies widely in this area (547–230 mm), with a clear dry and wet season, and 85% of the year's rainfall falls between May and October. The regional land and climate features are reflected in soils. In detail, mountain dryland soils are dispersed and have low organic matter [39]. People residing in these areas have responded to these challenges by developing many distinctive agroecosystems through long-term agricultural production, allowing them to produce a variety of agrifoods such as rice, wheat, barley, broad beans, tea, walnuts, coffee, pears, sugarcane, water chestnuts, honey, cattle, sheep, and fish. Seventy of these agrifood resources have been recognized and included in the bioculture project for agricultural heritage [7,40] (Figure 1).

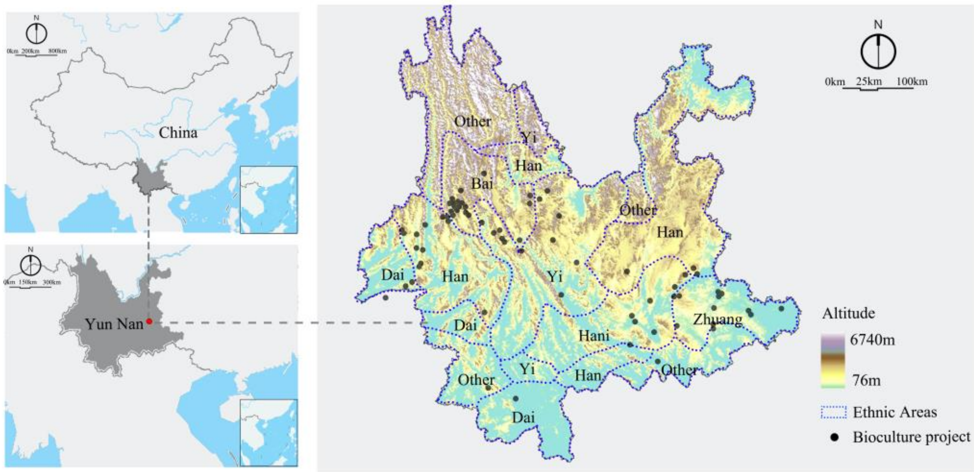

Figure 1. Topography and ethnic distribution of the study area.

Previous studies found that sustainable agrifood land assessment involves two dimensions, namely, the intrinsic factors such as crop type, area, and yield, as well as external factors such as climate, population, and society. Six agrifood land systems were selected for sustainable assessment. The criteria for selection were: (1) the retention of agricultural heritage sites; (2) complete data on agrifood production (2010–2020); (3) complete statistics on temperature, precipitation, population, and economy. The geographic data were driven from the Resource and Environment Science and Data Center of the Chinese Academy of Sciences [41]. Agricultural user group production data and economic and social data were derived from statistical yearbooks, including, but not limited to, the Yunnan statistical yearbook [39] and the Chinese ethnic statistics yearbook [42]. In addition, data on the ecological footprint and biocapacities of China, East Asia, and the world came from the Global Footprint Network [43].

2.2. Methods

2.2.1. Eco-Efficiency Analysis

Eco-efficiency analysis defines the footprint of the consumption of biological resources provided by available ecosystems as the ecological footprint, whereas the area of available bioproduction land is the biocapacity, both measured in global hectares [34,35]. In general, the ecological footprint of agrifood products, with agriculture, forestry, livestock, and fisheries as the main modes of production, and four biologically productive land types should be taken into account: cropland, forest products, grazing land, and fishing grounds [43]. To compare the eco-efficiency of agrifood land in different ethnic groups, China, East Asia, and the world, respectively, we have adopted an ecological footprint indicator per capita, which was calculated as follows:

$$EF_j = \frac{r_j \sum_{i=1}^{n} C_i}{(W_i \times n)_i} \quad (1)$$

In Equation (1), EF_j represents the ecological footprint per capita of agrifood land type j. C_i represents the annual average total production of agrifood land consumption. i and n represent the different types of agrifood land consumption items and the total population of the area, respectively. W_i means the world average production capacity. r_j is the equivalence factor of each agrifood land type. The equivalence factor is the ratio of the average productivity of a certain type of productive land to the average productivity of all productive land worldwide. In this paper, the equivalence factor is 2.8 for cropland, 0.2 for fishing grounds, 1.1 for forest product, and 0.5 for grazing land.

$$BC_j = A_j \times r_j \times \mathrm{P}_j \tag{2}$$

BC_j is the per capita biocapacity of agrifood land type j; A_j is the ecologically productive land area per capita of agrifood land type j, which can be calculated by dividing the world average productivity of each type of consumer crop by that type of consumer product; P_j represents the yield factor of land type j, it is the ratio of the average productivity of a certain type of land to the average productivity of that land type on a global scale, and it minuses 12% of the land that is used for biodiversity conservation.

The ecological benefit index is used to evaluate the ecological sustainability of agrifood land in this study. Prior studies have assessed the ecological benefits of a region or industry through the method of subtracting biocapacity from the ecological footprints, resulting in ecological surplus or ecological deficit [44,45]. However, this dichotomy is imprecise in representing complex spatial and temporal variations. Therefore, we propose ecological benefits to assess this change based on the ecological supply and demand balance index [46]. The result is classified into three types and five levels (Table 1), with the calculation formula as follows:

$$EB = \frac{BC}{EF} = \frac{\sum_{j=1}^{n} BC}{\sum_{j=1}^{n} EF} \tag{3}$$

Equation (3) defines the ecological benefit as EB, which assesses regional ecological conditions. BC represents the sum of the biocapacity of land type j. Meanwhile, EF represents the sum of the ecological footprint of land type j.

Table 1. Evaluation criteria for the ecological sustainability of agrifood land of various ethnic groups in Yunnan.

Types	Sustainable Status	Ecological Benefit
Agrifood land ecological affluent	Affluent	$1.1 < EB$
Agrifood land ecological balance	Balance	$1 < EB \leq 1.1$
	Deficit	$0.9 < EB \leq 1.0$
Agrifood land ecological deficit	Overload	$0.7 < EB \leq 0.9$
	Severe overload	$EB \leq 0.7$

2.2.2. Redundancy Analysis

Redundancy Analysis (RDA) is a method of multiple regression analysis used to visualize the contribution of different independent variables to the response variable through a two-dimensional Biplot graph. In the Biplot graph, each variable is represented by a vector whose direction and length indicate its contribution, whereas each sample is represented by a point reflecting performance under different variable combinations [47]. RDA analysis was conducted using Canoco 5 software (Microcomputer Power Corporation). Firstly, Detrended Correspondence Analysis (DCA) was utilized to obtain the gradient length of the sorting axis, and RDA analysis was an appropriate option if the gradient was less than 3. Secondly, 16 agrifood production factors and 9 environmental factors were chosen as independent variables for RDA screening. The Monte Carlo permutation test was employed to quantify the contribution rate of each factor to the change in eco-efficiency [48]. Statistical significance was at $\leq$0.05 for all analyses.

3. Results

3.1. Eco-Efficiency of Agrifood Land in Different Ethnic Groups

The ecological footprint of agrifood land varies by ethnic group and changes over time. As shown in Figure 2 and Table 2, the total ecological footprint of agrifood land for all ethnic groups increased from 0.33 (gha per person) in 2010 to 0.43 (gha per person) in 2015 and 2020, which were less than one-half of the values in China, East Asia, and the world. Dai had consistently higher ecological footprints with 0.56, 0.59, and 0.64 (gha per person) in 2010, 2015, and 2020, respectively. In contrast, the Miao had a lower ecological footprint in 2010 and 2020 but showed an increase in 2015, with an average of 0.38 (gha per person) (Figure 2).

The total biocapacity of agrifood land increased from 0.24 (gha per person) in 2010 to 0.37 (gha per person) in 2015 but slightly decreased to 0.35 (gha per person) in 2020. Dai had the highest biocapacity among all ethnic groups in these years, with 0.58, 0.55, and 0.53 (gha per person) in 2010, 2015, and 2020, respectively. The biocapacity of the Bai rapidly increased from 0.28 in 2010 to 0.54 in 2015 but decreased to 0.42 (gha per person) in 2020. Conversely, Zhuang's biocapacity was lower in 2020 at 0.27 compared to 0.35 (gha per person) in 2010 (Figure 3, Table 2).

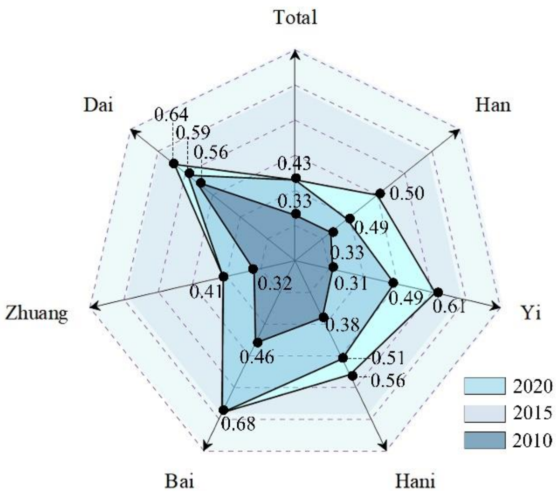

Figure 2. Ecological footprint of agrifood land between six ethnic groups in 2010, 2015, and 2020 (gha per person).

Table 2. The agrifood land eco-efficiency for total ethnic groups, compared with those for China, East Asia, and the World.

Geographic Region	Ecological Footprint (gha per Person)			Biocapacity (gha per Person)			Ecological Benefit		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
Han	0.33	0.39	0.50	0.20	0.31	0.31	0.61	0.79	0.62
Yi	0.31	0.49	0.61	0.15	0.31	0.40	0.48	0.63	0.66
Hani	0.38	0.51	0.56	0.18	0.42	0.42	0.47	0.82	0.75
Bai	0.46	0.68	0.68	0.28	0.54	0.48	0.61	0.79	0.71
Zhuang	0.32	0.41	0.41	0.22	0.36	0.27	0.69	0.88	0.66
Dai	0.56	0.59	0.64	0.58	0.55	0.53	1.04	0.93	0.83
Total	0.33	0.43	0.43	0.24	0.37	0.35	0.71	0.86	0.82
China	0.89	0.98	1.00	0.79	0.82	0.79	0.89	0.84	0.79
East Asia	0.93	1.00	1.03	0.79	0.81	0.81	0.85	0.81	0.79
World	1.01	1.01	1.01	1.63	1.56	1.51	1.61	1.54	1.50

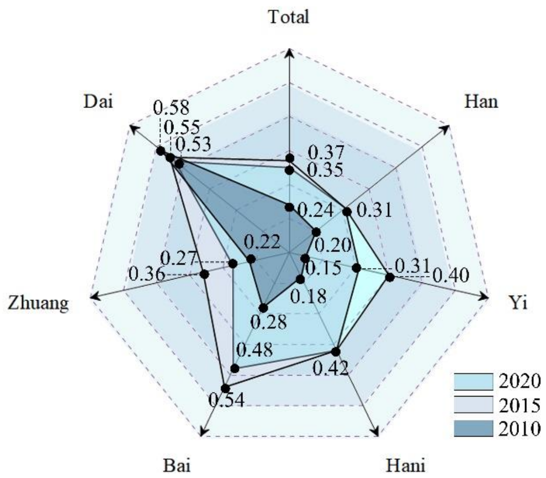

Figure 3. Biocapacity of agrifood land between six ethnic groups in 2010, 2015, and 2020 (gha per person).

From 2010 to 2020, the total ecological benefit of agrifood land showed an increasing trend, reaching a peak of 0.86 in 2015 before slightly declining to 0.82 by 2020. Despite the fact that agrifood lands of most ethnic groups were in an ecological deficit or overload state in the past 10 years, a comparison of the value changes showed that the ecological benefits of the six ethnic groups were different. Among them, the added values of the ecological benefits of agrifood land for Hani, Yi, and Bai were at least 0.28, 0.17, and 0.10, respectively. The value of Dai decreased significantly by 0.21. In addition, the values of the Han and Zhuang increased by 0.01 and decreased by 0.03, respectively, with little change (Figure 4, Table 2).

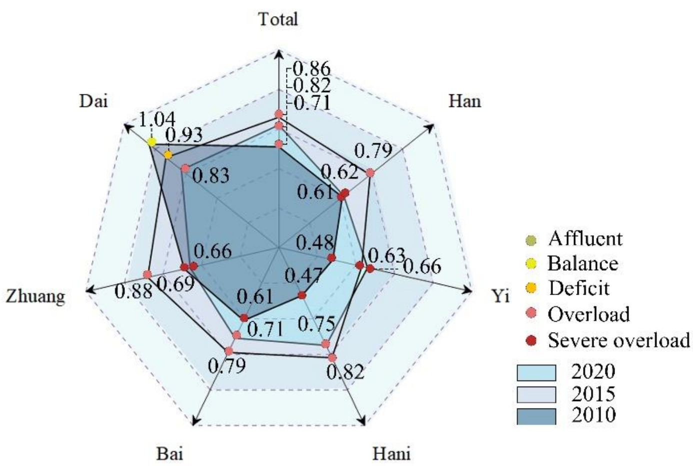

Figure 4. Ecological benefit of agrifood land between six ethnic groups in 2010, 2015, and 2020.

3.2. Contribution of Agrifood Production Factors to Agrifood Land Eco-Efficiency

Figures 5 and 6 show the contribution of 16 yield and acreage factors to the eco-efficiency of agrifood land for each ethnic group. The study identified vegetable yield (32.8%), fisheries products yield (20.8%), forestry products yield (13.3%), pulses acreage (19.2%), fruit acreage (24.2%), and livestock acreage (15.8%) as the primary contributors to eco-efficiency (Figure 7). Additionally, some factors exhibited significant variations over time, with fruit yield increasing from 33.8% in 2010 to 54.2% in 2020, whereas forestry acreage increased from 6.7% in 2015 to 21.1% in 2020 (Figure 8).

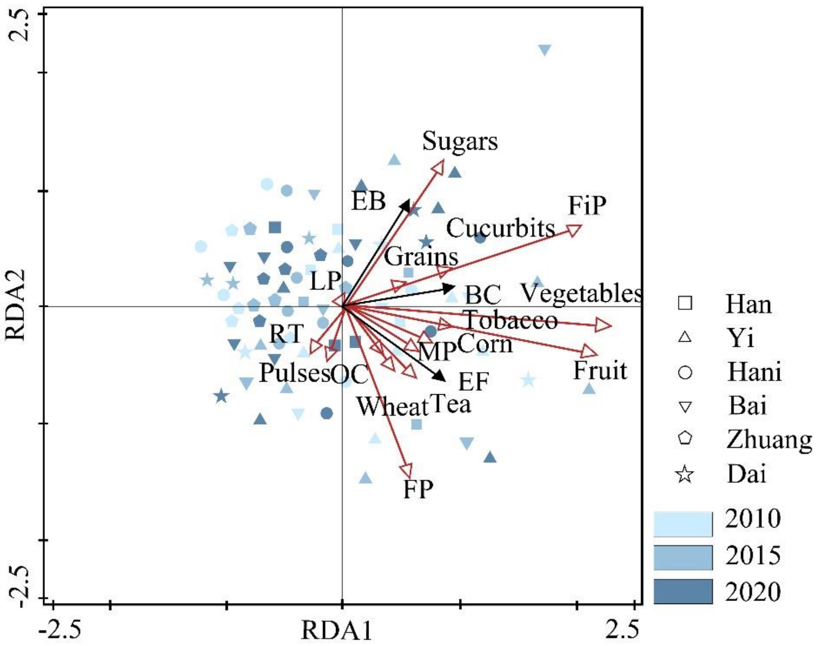

Figure 5. Agrifood land eco−efficiency is explained by the agrifood yield factor. Note: RT: roots and tubers; OC: oil crops; MP: medicinal plants; FP: forestry products; FiP: fisheries products; LP: livestock products; EF: ecological footprint; BC: biocapacity; EB: ecological benefit.

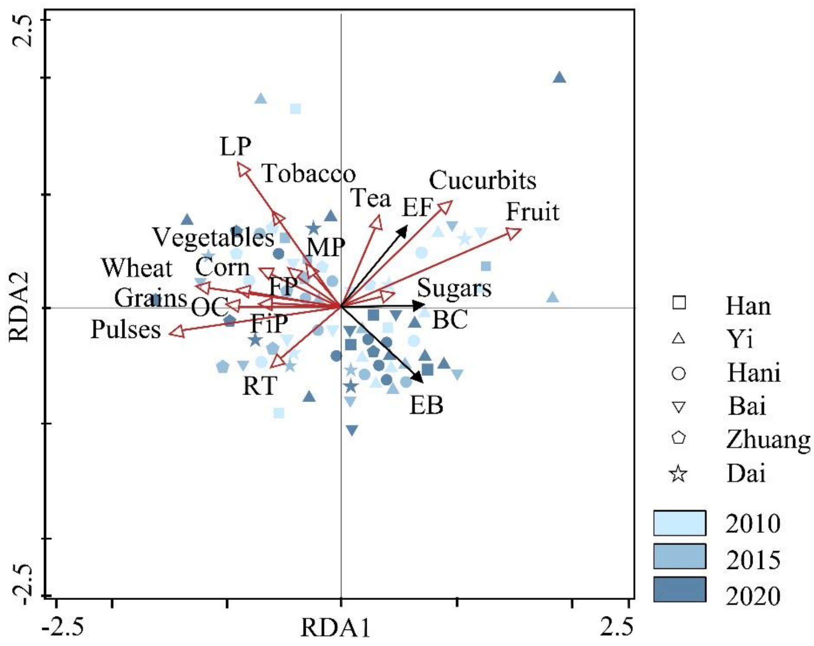

Figure 6. Agrifood land eco−efficiency is explained by the agrifood acreage factor. Note: RT: roots and tubers; OC: oil crops; MP: medicinal plants; FP: forestry products; FiP: fisheries products; LP: livestock products; EF: ecological footprint; BC: biocapacity; EB: ecological benefit.

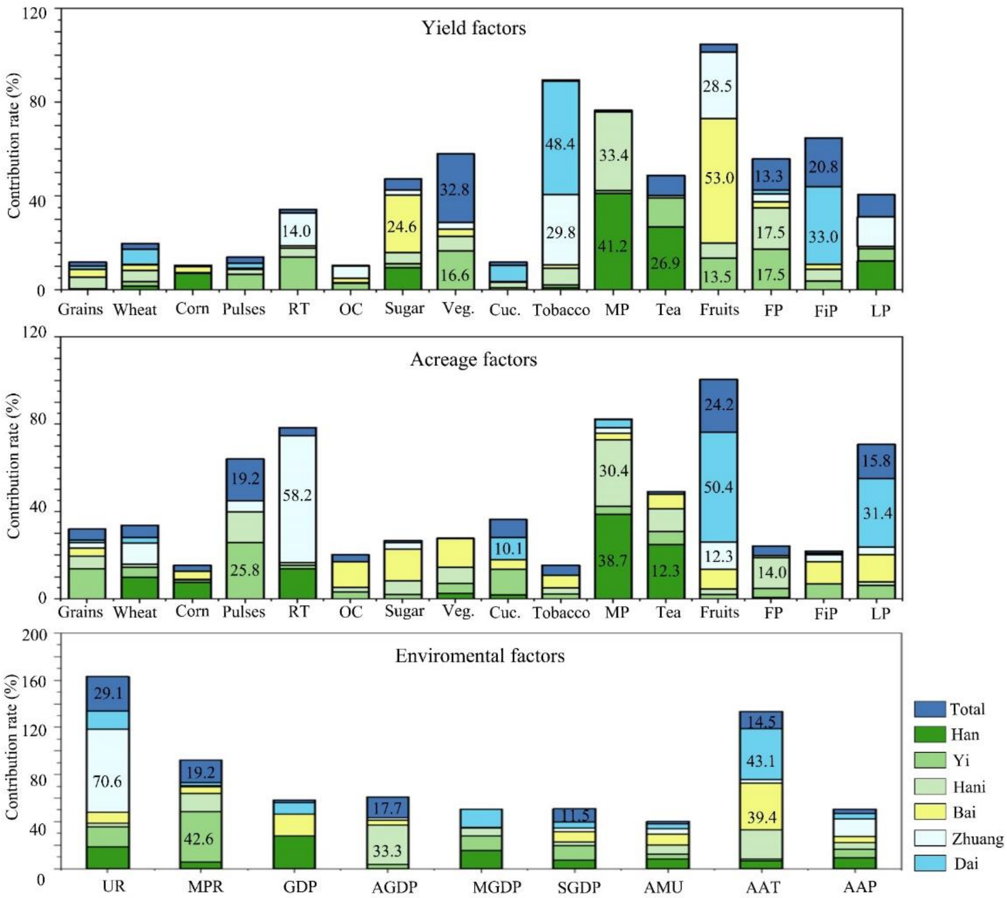

Figure 7. Contribution rate of agrifood production and environmental factors to agrifood land eco-efficiency. Note: RT: roots and tubers; OC: oil crops; Veg.: vegetables; Cuc.: cucurbit; MP: medicinal plants; FP: forestry products; FiP: fisheries products; LP: livestock products; UR: urbanization rate; MPR: minority population ratio; GDP: gross domestic product; AGDP: agricultural GDP; MGDP: manufacturing industry GDP; SGDP: service industry GDP; AMU: number of agricultural machinery units; AAT: annual average temperature; AAP: annual average precipitation.

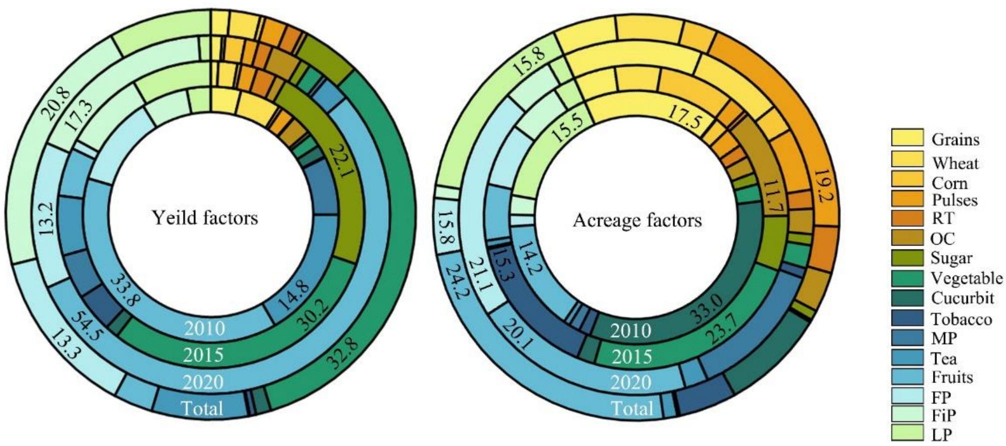

Figure 8. Contribution rate of agrifood production to agrifood land eco-efficiency in 2010, 2015, and 2020.

Additional analysis revealed differences in the contribution of these yield and acreage factors to the eco-efficiency of agricultural land across ethnic groups. Specifically, Medical plants yield (41.2%) and acreage (38.7%), as well as tea yield (26.9%), were the main factors affecting the eco-efficiency of Han. The main factors influencing the eco-efficiency for Yi were forestry product yield (17.5%) and pulses planted acreage (25.8%). The main factors affecting eco-efficiency of the Hani group were the yield (33.4%) and acreage (30.4%) of medical plants, as well as the yield of forestry products (17.5%). Fruit production (50.3%) and sugars production (24.6%) were the most important factors affecting the eco-efficiency of Bai. For Zhuang, tobacco (29.8%) and fruit yield (28.5%) and roots and tubers acreage (58.2%) were the main factors affecting eco-efficiency. In the case of Dai, tobacco (48.4%) and fisheries production (33.0%) and fruit (50.4%) and livestock acreage (31.4%) were the major factors that affected the eco-efficiency (Figure 7).

3.3. Contribution of Environmental Factors to Agrifood Land Eco-Efficiency

The contribution of nine environmental factors on the eco-efficiency of agrifood land across different ethnic groups was shown in Figure 9. Based on the results, urbanization rate (29.1%), minority population ratio (19.2%), annual average temperature (14.5%) agricultural GDP (17.7%), and service industry GDP (11.5%) were identified as the key determinants of eco-efficiency (Figure 10). In addition, factor contribution rates had changed substantially over time, such as the contribution of urbanization rates of 28.9% in 2010, 31.4% in 2015, and 20.1% in 2020, with 2015 as the peak year. Similarly, the contribution rate of annual average temperature was 20.1% in 2010, 26.9% in 2015, and 21.0% in 2020. The minority population ratio's contribution rate (24.9%) did not advance until the year 2020.

Further analysis also revealed differences in the contribution of these environmental factors to the eco-efficiency of agricultural land across ethnic groups. For example, the urbanization rate had a high contribution to Zhuang (70.6%), whereas the minority population ratio had a greater influence on Yi (42.6%). The annual average temperature had the highest contribution for Bai (39.4%) and Dai (43.1%). Moreover, agricultural GDP (33.3%) had a significant contribution to Hani (Figure 7).

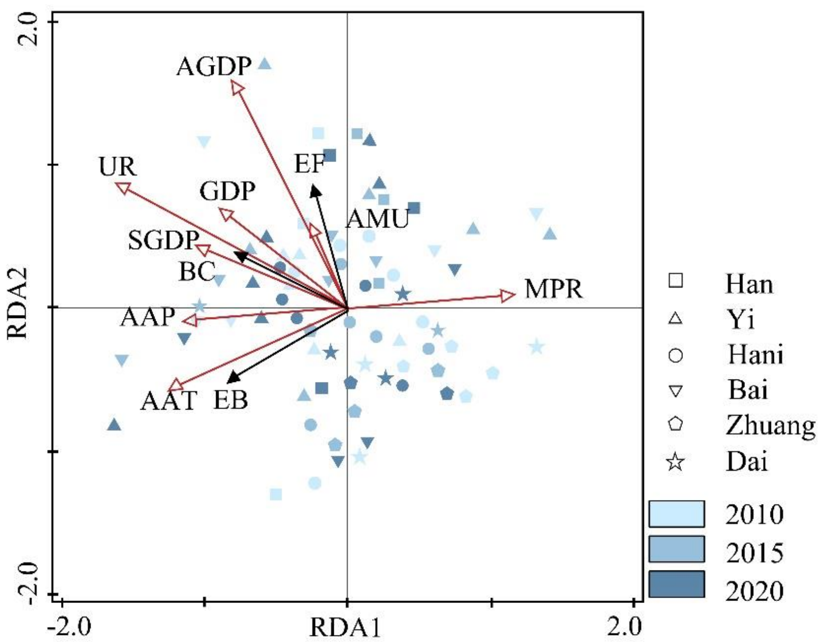

Figure 9. Agrifood land eco−efficiency is explained by environmental factors. Note: UR: urbanization rate; MPR: minority population ratio; GDP: gross domestic product; AGDP: agricultural GDP; MGDP: manufacturing industry GDP; SGDP: service industry GDP; AMU: number of agricultural machinery units; AAT: annual average temperature; AAP: annual average precipitation; EF: ecological footprint.

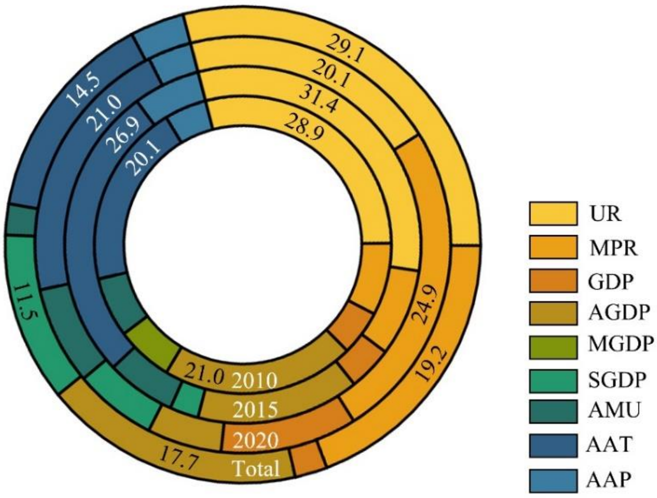

Figure 10. Contribution rate of environmental factors to Agrifood land eco-efficiency in 2010, 2015 and 2020. Note: UR: urbanization rate; MPR: minority population ratio; GDP: gross domestic product; AGDP: agricultural GDP; MGDP: manufacturing industry GDP; SGDP: service industry GDP; AMU: number of agricultural machinery units; AAT: annual average temperature; AAP: annual average precipitation; EF: ecological footprint.

4. Discussion

The purpose of this study was to propose some quantitative models and methods for assessing the sustainability and explanatory factors of ethnic agrifood lands in Yunnan. In comparison to previous studies [36–38], we provided new insights into the sustainability of agrifood lands that d facing social change and climate disruption in ethnic areas, not limited to resource-intensive areas or industries. Methodologically, we employed a robust and universal model for uncovering the complex relationship between the analysis of sustainability and explanatory factors. One of these achievements was the visual representation and scientific evidence of superimposed radar maps and redundant analysis methods as ecological indicators and drivers of the agrifood lands. This was the original contribution of the present study.

The second contribution was the objective description of the sustainability status of ethnic agrifood lands. The scope of our research extended from the agricultural heritage sites to the areas in which they are located and quantitatively revealed the low ecological deficit of the agrifood lands in Yunnan, i.e., the ecological footprint and biocapacities of the agrifood lands varied in the lower range from 2010 to 2020, which was much lower than the ecological footprint and biocapacities of China, East Asia, and the world during the same period [43]. However, this result did not indicate that Yunnan's agrifood land had sufficient ecological resilience and development potential but reflected the fragility of its mountainous ecological environment, as mentioned in the literature review [25]. In the context of ecological deterioration, local governments and management agencies must pay close attention to the changes in the ecological footprints and biocapacities of these areas to avoid a recurrence of the rapid deterioration of the ecological benefits of agrifood land of all ethnic groups from 2010 to 2015 (Table 2).

Many studies of agricultural eco-efficiency emphasize the importance of crop types to ecological benefits but neglect further analysis of the specific contributions of the drivers of ethnic crop production [49,50]. For this reason, we analyzed the contribution of yield and acreage factors to the eco-efficiency of each ethnic agrifood land through redundancy analysis. It was found that different types of crops made a significant contribution to the eco-efficiency at different times and in different ethnic groups, namely, cash crops (e.g., vegetables, fruits, tea, medicinal plants, tobacco, etc.), forestry, fisheries, and livestock products have a major contribution, whereas staple grains (e.g., pulses for Yi, roots and tubers for Bai, etc.) make only a minor contribution. One possible explanation for these results was the adaptability of traditional agriculture in Yunnan's mountainous regions. specifically, not all ethnic locations are suitable for growing staple foods such as grains, soybeans, and corn. However, traditional agriculture, such as the tea garden system of Han, the taro farming system of Zhuang, and the pear–crop composite system of Bai, was sustainably adapted to local topography, altitude, and soil. This finding was different from what has been found, where the staple grain product had crucial value for food security and sustainable agricultural ecosystems [51–53]. Maintaining the land adaptability of typical agrifood crops, as well as controlling the scale of staple crops and foreign cash crops, will thus be an essential direction for promoting the sustainable development of ethnic agrifood lands in Yunnan.

The study also investigated the contribution of environmental factors to the eco-efficiency of ethnic agrifood lands. These findings highlighted the influence of a variety of environmental factors such as urbanization rate, annual average temperature, minority population ratio, and agricultural GDP on the eco-efficiency of agrifood land. A key finding of the study was the Rule of Reversed U, the contribution of urbanization rate to the eco-efficiency of agri-food land, which rose between 2010 and 2015 and gradually declined between 2015 and 2020. One possible hypothesis was that it contributed to a higher temperature and food demand; to a certain extent, to advances in agricultural production techniques; and to the positive effects of plant growth and animal husbandry, thus contributing to the eco-efficiency of ethnic agrifood lands, from 2010 to 2015, when urbanization increased more slowly (35.8% to 41.6%). During the rapid urbanization growth (41.6% to 50.0%) between 2015 and 2020, positive factors such as temperature were partially offset by the negative impacts of urbanization, thus contributing less to the eco-efficiency of ethnic agrifood lands. Prior studies have shown that high rates of urbanization and extreme climate will result in reductions in agricultural land, irrigation water crises, and an increase in ecological footprints such as pest propagation [15–18]. Thus, policies that both protect agricultural land and enable urban development are necessary to mitigate the negative impacts of urbanization on the local environment and agriculture. This could be achieved by controlling the expansion of urban areas, promoting the development of small towns and villages, as well as strengthening land-use planning and management. Especially, in the Zhuang group, where the urbanization rate was the highest, as well as in Bai and Dai areas, where the annual average temperature contribution was the highest, adaptive measures are needed to maintain eco-efficiency.

We also found that the minority population ratio was crucial for maintaining the eco-efficiency of agrifood lands by providing an ecological perspective on the impact of urbanization, rural livelihood shifts, and economic development on agricultural sustainability. For example, the ethnic minority population of Yi contributes at a high level, which may be related to their reliance on traditional and sustainable farming practices. Nevertheless, higher levels of urbanization provide more jobs and higher economic incomes, which, in return, lead to the loss of indigenous populations. In these areas, traditional food demand and production are likely to decline, which can result in less eco-efficiency in the use of farmland for food production [16,18,19]. Policymakers must, therefore, consider the need to maintain the population base of all ethnic groups with solutions for increasing people's economic incomes and livelihoods, in order to promote the sustainability of agrifood and land use by all ethnic groups in Yunnan.

5. Conclusions

5.1. Limitations

Analyzing the eco-efficiency of various factors may provide insight into the sustainability of agrifood land in Yunnan. However, several limitations should be addressed in future research. First, limited data collection hampers the validation of findings over a longer period. The inclusion of a longer time frame in future studies may provide a more comprehensive view. Secondly, our study employs redundancy analyses to determine the impact of factors such as agrifood types, urbanization, minority population ratio, economic development, and climate change on agrifood land sustainability, but several environmental factors that may impact agrifood land sustainability are not included in this analysis. Future research may increase synergies or offset the interaction of variables such as policy, culture, and transport factors with current factors for agricultural sustainability. Finally, there is a need for more research in the areas of agrifood land protection and sustainable development.

5.2. Practical Implications

In this study, we evaluated the ecological sustainability and explanatory factors of agrifood lands in six ethnic groups in Yunnan through superimposing radar maps and redundancy analysis. The results showed that the ecological benefit of agricultural land in Yunnan fluctuated with a low ecological deficit in the period of 2010–2020, and the ecological benefits of different ethnic groups varied markedly. Subsequent analysis identified several key factors affecting the eco-efficiency of agrifood land among these groups, including agricultural production and environmental factors. In terms of agricultural production factors, redundant analysis based on yield and acreage showed that cash crops, forestry, fisheries, and livestock contributed more to eco-efficiency than staple food. In terms of environmental factors, we found that the urbanization rate had a significant influence on the eco-efficiency contribution rate of ethnic agrifood land, as well as the annual average temperature and ethnic population rate. The results of the study provided valuable insights for policymakers and practitioners seeking to promote ecologically sustainable development in ethnic areas of Yunnan through effective agrifood land management. The results could also be used to investigate agrifood land development capacity in other regions and countries to understand the status of sustainable agrifood land development.

5.3. Future Research

Future research may increase synergies or offset the interaction of variables such as policy, culture, and transport factors with current factors for agricultural sustainability. Finally, there is a need for more research in the areas of agrifood land protection and sustainable development. Future research should explore potential interventions to address the negative impacts of agrifood cultivation and socio-economic and climatic factors on the sustainability of agrifood lands.

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